3.31 Gun Movement Functional Element Sensitivity

Subroutine MOVGUN in *RADGUNS* simulates the gun servo system that moves the guns in response to signals sent by the FCC. Once each radar scan period, the FCC model (FIRCON) computes two gun aiming coordinates and sends them to this subroutine which calculates the response of the gun servos. Aim point azimuth β_P and current gun boresight azimuth GUN_{AZ} are used in the azimuth servo model to produce a new value for GUN_{AZ}. Angles for elevation, φ_P and GUN_{EL} are treated in an analogous manner.

Data Items Required

Data Item		Accuracy	Sample Rate	Comments
8.2.1	Aimpoint azimuth	±0.1 deg	10 Hz	AKA turret Az
8.2.2	Aimpoint elevation	±0.1 deg	10 Hz	AKA turret El

3.31.1 Objectives and Procedures

The method used to examine the gun movement sensitivity was to exercise *RADGUNS* under the following conditions:

a. Model mode: SNGL/RADR/LLL
b. Target RCS: 1.0 m^2
c. Target altitude: 200 m
d. Target speed: 50, 200, 300 m/s
e. Flight path: LINEAR, 0- and 1-K offsets; CIRCL1, R = 2000 m
f. Radar type: RAD1
g. Guns: Enabled
h. Output: Gun azimuth, gun elevation, and time

Table 3.31-1 lists the simulation run matrix used to evaluate this functional element, which was designed to span a reasonable range of target velocities, ranges, and flight paths. Zero-offset, linear, and circular flight paths were constructed to reduce the number of variables affecting outputs for those specific cases.

TABLE 3.31-1. Run Matrix for Evaluating the Gun Movement Functional Element.

Type	Velocity (m/s)	Variables	Constants
Linear, 0K Offset Linear, 0K Offset	50 300	Elevation angle Range	Azimuth
Circle, R=2000 m Circle, R=2000 m	50 200	Azimuth	Range Elevation
Linear, 1K Offset Linear, 1K Offset	50 300	Azimuth Elevation Range	None

Variance analysis was used to ascertain gun movement sensitivity relative to different velocities, ranges, and flight paths. In each case examined, a comparison was made of the gun pointing angle versus the commanded angle (output from the FCC) and the true azimuth and elevation angles. Table 3.31-2 lists variable names used in the graphics of this section. Table 3.31-3 lists additional conditions applicable to each run.TABLE 3.31-2. List of Variable Names Used in Figures.

Variable	Definition
AZDEG	True azimuth angle in degrees
AZDIFFnnn	Difference in azimuth angle between gun and true in degrees for nnn m/s velocity
BETADEG	Commanded azimuth angle in degrees
BETAnnn	Commanded azimuth at nnn m/s velocity
ELDEG	True elevation in degrees
ELDIFFnnn	Difference in elevation angle between gun and true in degrees for nnn m/s velocity
ELRATE	True elevation angular rate in degrees/second
GUNAZ	Gun azimuth pointing angle in degrees
GUNAZnnn	Gun azimuth pointing angle at nnn m/s velocity
GUNEL	Gun elevation pointing angle in degrees
GUNELnnn	Gun elevation pointing angle at nnn m/s velocity
PHIDEG	Commanded elevation angle in degrees
PHIDEGnnn	Commanded elevation at nnn m/s velocity

TABLE 3.31-3. Additional Conditions.

Element	Status
Search Radar Mode	Perfect Cuing
MTI	Off
FCC Model	First Order
Clutter	Disabled
Multipath	None
Terrain (Hills)	None
Countermeasures (Jamming)	None

3.31.2 Results

The circular flight paths were investigated for angle variance. Figures 3.31-1 and 3.31-2 show the azimuth and elevation values for the 50 m/s case. As expected, the azimuth gun pointing angle maintains a relatively constant lead over actual azimuth (clockwise flight path), and the elevation is almost constant over the duration of the run. Some differences can be seen in these two figures between commanded angle values and gun aim points. Figure 3.31-3 shows the increasing and decreasing differences in lead angle that result from the model of the gun servo mechanism. Elevation differences are similar in nature but an order of magnitude smaller for this case.

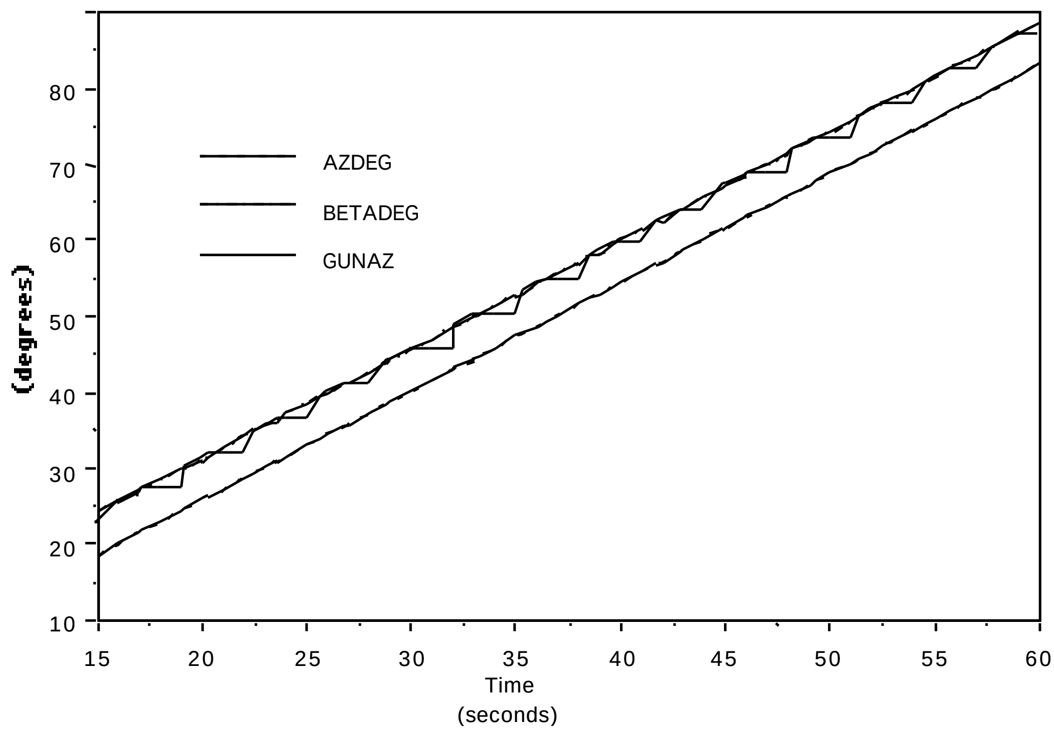

FIGURE 3.31-1. True Azimuth, Commanded Azimuth, and Gun Azimuth (Target Speed = 50 m/s, Circular Flight Path).

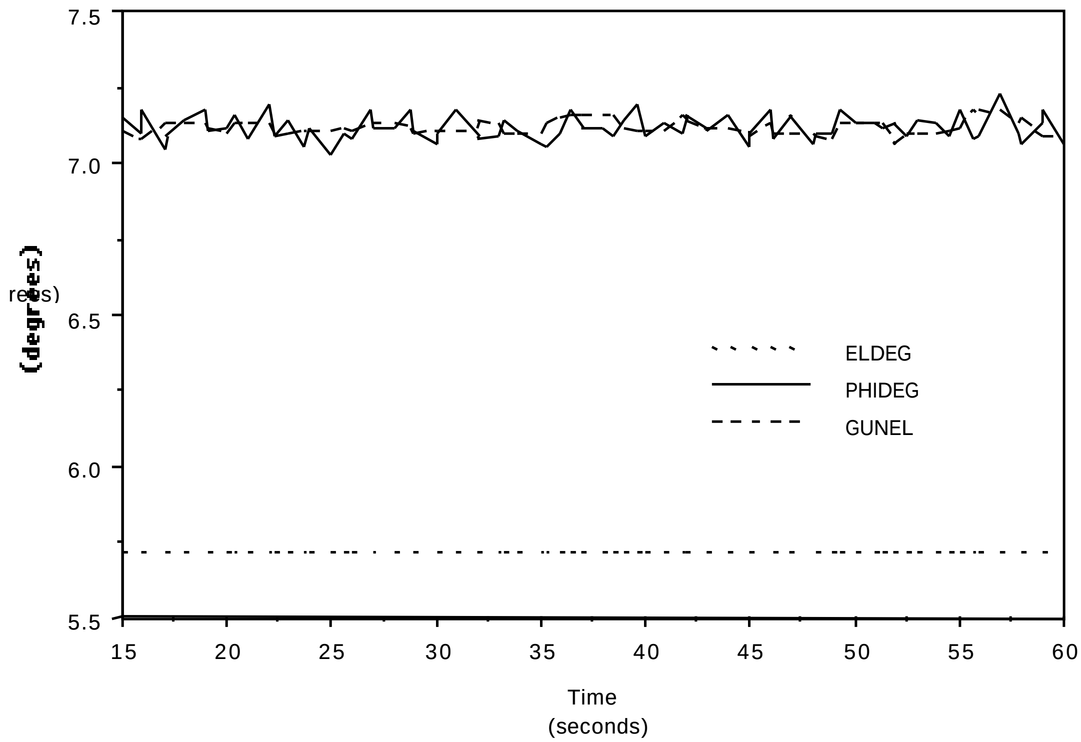

FIGURE 3.31-2. True Elevation, Commanded Elevation, and Gun Elevation (Target Speed = 50 m/s, Circular Flight Path).

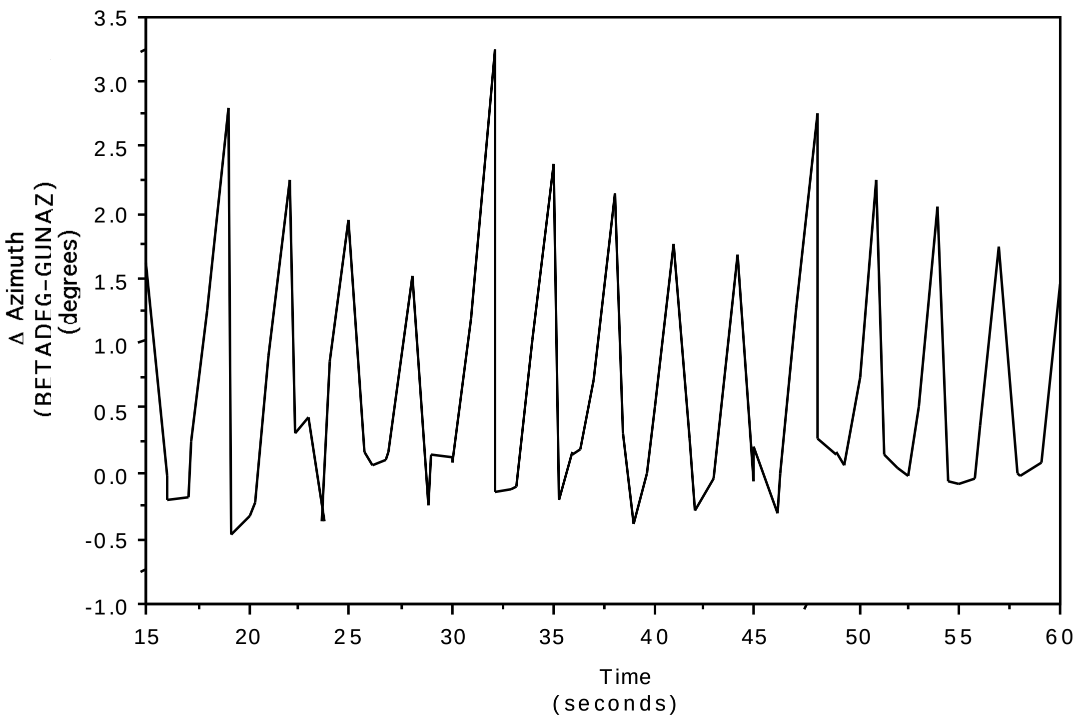

FIGURE 3.31-3. Difference Between Commanded Azimuth and Gun Azimuth (Target Speed = 50 m/s).

The 200 m/s circular data is shown in Figures 3.31-4 and 3.31-5. Note that the characteristic shapes of these and the 50 m/s curves are similar. Differences between commanded and gun pointing azimuth angles are shown in Figure 3.31-6 which shows the elevation differences are two orders of magnitude smaller than these. Table 3.31-4 summarizes the gun pointing angle variance for both runs.

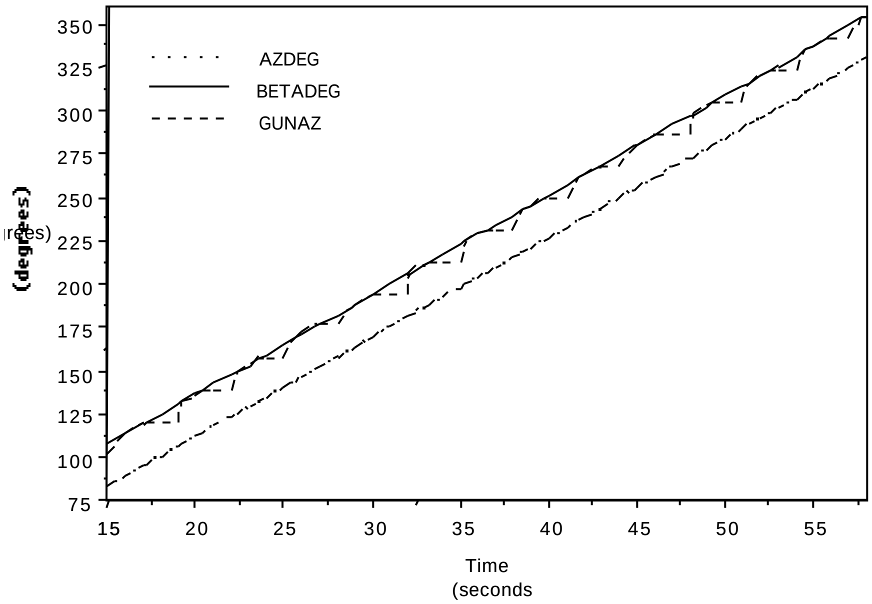

FIGURE 3.31-4. True Azimuth, Commanded Azimuth, and Gun Azimuth (Target Speed = 200 m/s, Circular Flight Path).

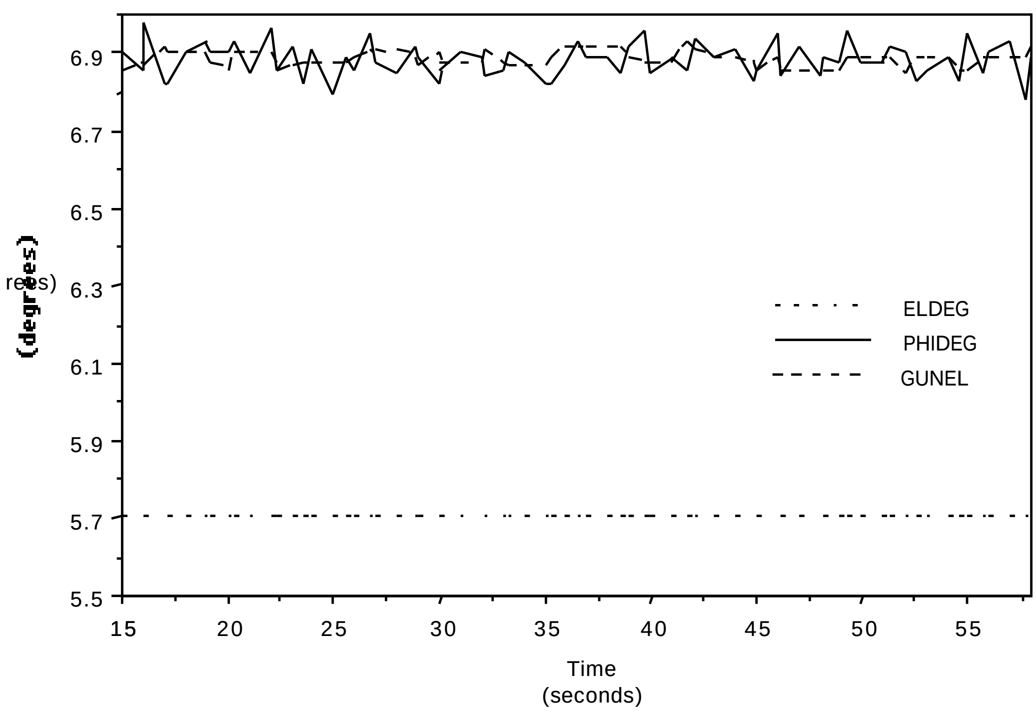

FIGURE 3.31-5. True Elevation, Commanded Elevation, and Gun Elevation (Target Speed = 200 m/s, Circular Flight Path).

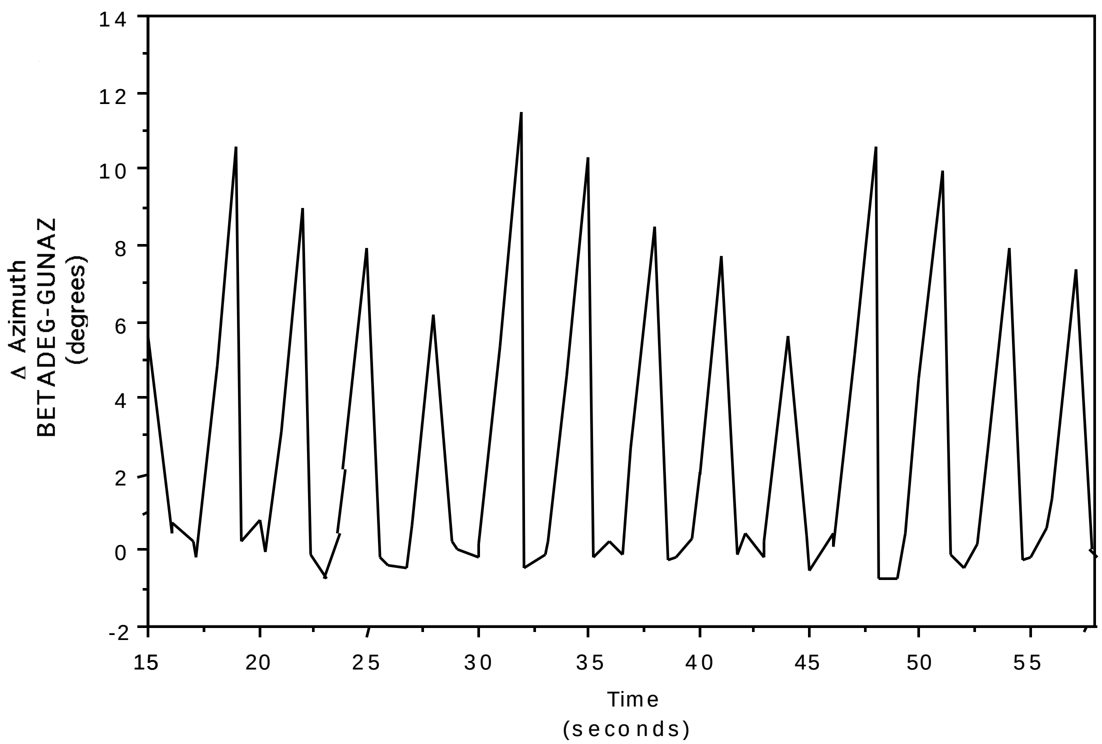

FIGURE 3.31-6. Difference Between Commanded Azimuth and Gun Azimuth (Target Speed = 200 m/s).

TABLE 3.31-4. Gun Pointing Data for Circular Flight Path by Target Velocity.

	Velocity (m/s)	Gun Pointing Angle	Mean Value (deg)	Standard Deviation (deg)
Lead	50	Azimuth	5.01	0.8685
Angles	200	Azimuth	22.64	3.472
Superelevation	50	Elevation	1.41	0.0228
Angles	200	Elevation	1.18	0.0188

The linear, zero-offset cases were designed to eliminate azimuth variance from the analysis. Figure 3.31-7 shows very small elevation fluctuations until just before the break lock point in each run. This case results in a break lock on every run because absolute elevation angle limits are always exceeded when the target flies directly overhead.

Figure 3.31-8 shows elevation angle variance for both the slow and fast speed cases. With the head given proportionately greater superelevation angle to correct for its higher closure rate. As can be seen, gun elevation angle sensitivity requires a precision on the order of ould be necessary for smaller variations in speed.

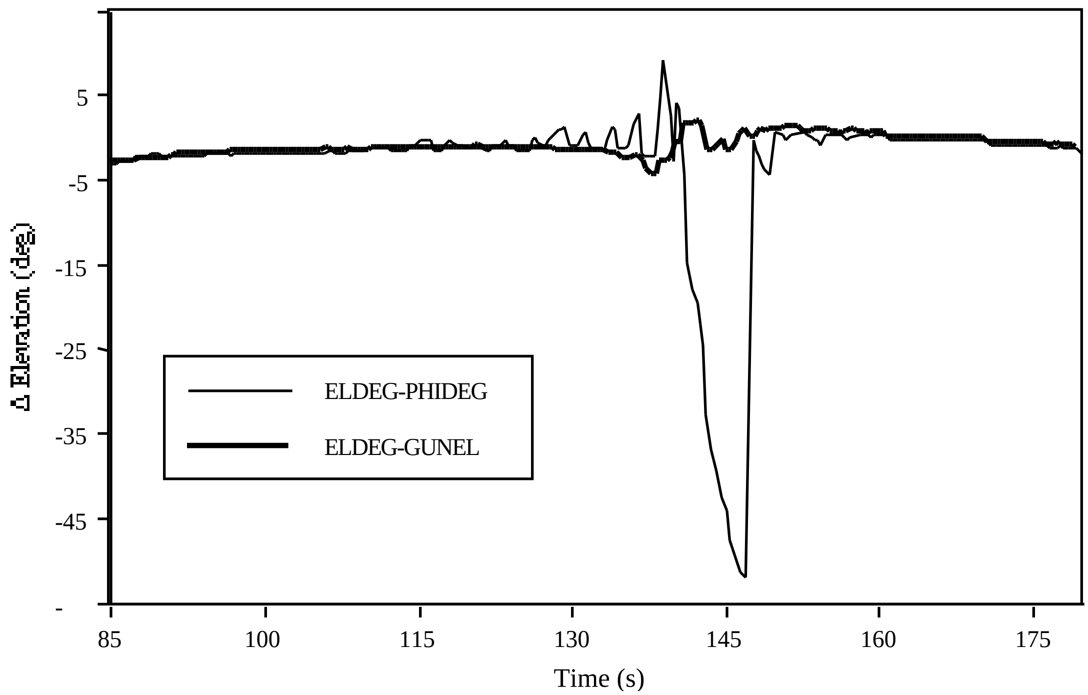

FIGURE 3.31-7. Difference Between True Elevation and Commanded Elevation, and True Elevation and Gun Elevation (0-K Offset, Target Speed = 50 m/s).

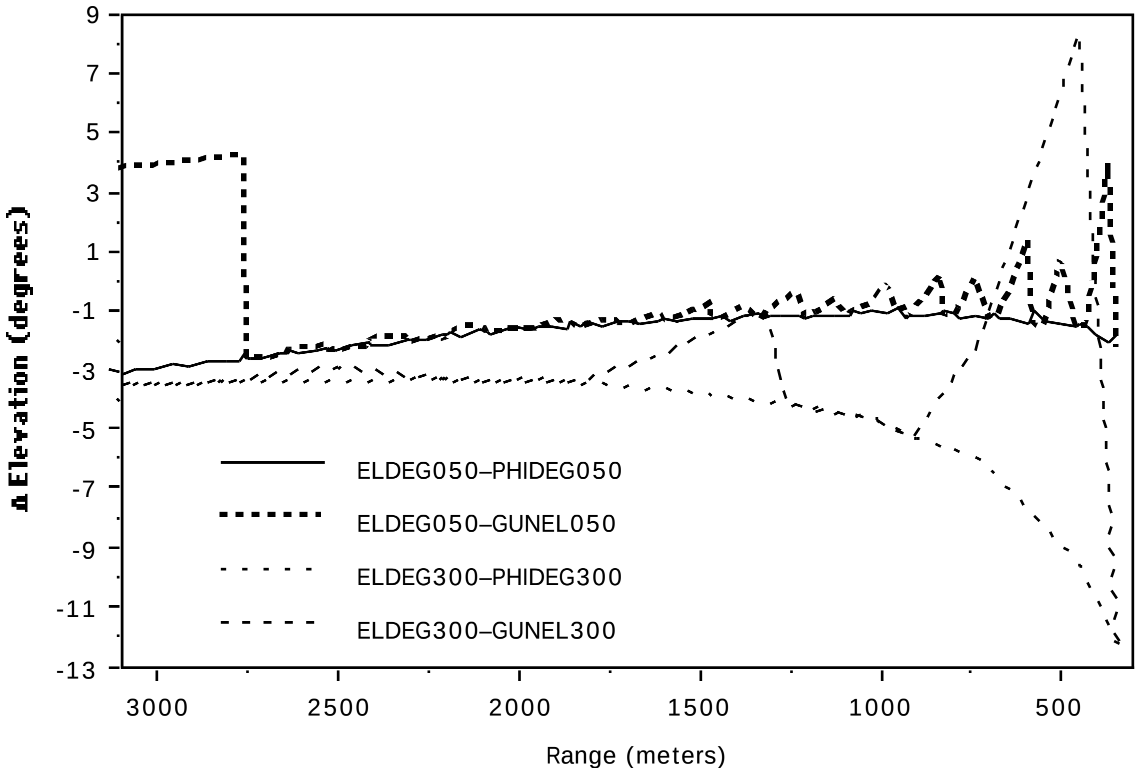

FIGURE 3.31-8. Difference Between True Elevation and Commanded Elevation, and True Elevation and Gun Elevation (0-K Offset, Target Speed = 50 and 300 m/s).

A 1-km offset was run at two different velocities. Figure 3.31-9 shows a composite of the azimuth deltas. Here, the small difference between commanded and pointing azimuths over a wide velocity band indicates a requirement for azimuth angular measurement precision of at least

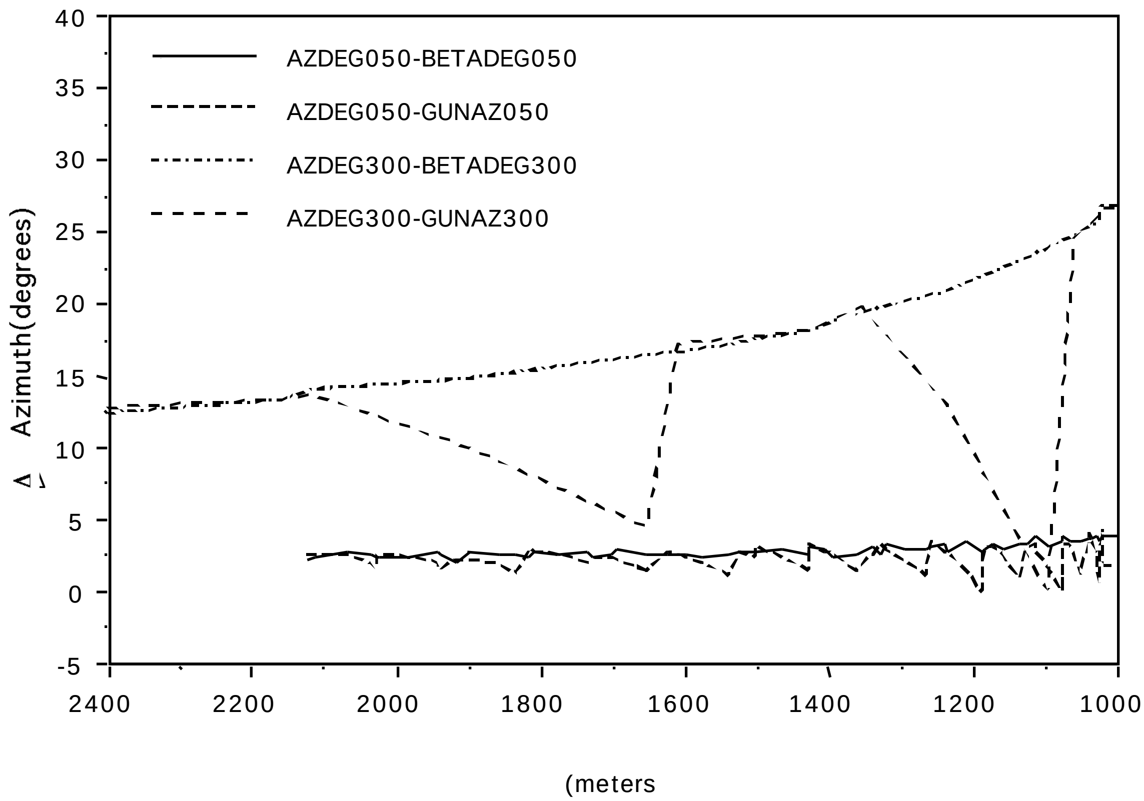

FIGURE 3.31-9. Difference Between True Azimuth and Commanded Azimuth, and True Azimuth and Gun Azimuth (1-K Offset, Target Speed = 50 and 300 m/s).

The 1-km offset elevation data is presented in Figure 3.31-10. In the gun elevation pointing angle element, an angular precision sensitivity on the order of .1 deg is necessary. Range variance does not require high precision, because doubling the range yields only a 2-deg change in elevation angle difference.

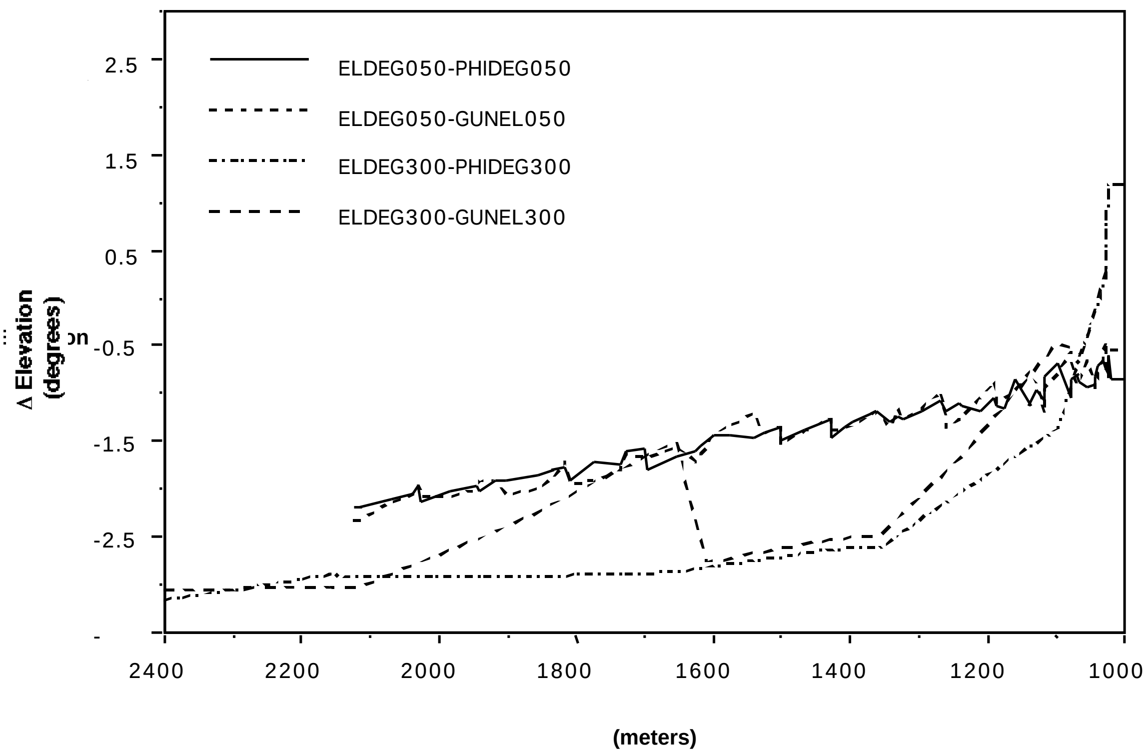

FIGURE 3.31-10. Difference Between True Elevation and Commanded Elevation, and True Elevation and Gun Elevation (1-K Offset, Target Speed = 50 and 300 m/s).

In summary, Table 3.31-5 lists the parametric sensitivity requirements for the Gun Movement functional element:

TABLE 3.31-5. Parametric Sensitivity Requirements for the Gun Movement Functional Element.

Parameter	Sensitivity
Range	
Position	
GUNAZ	
GUNEL	

3.31.3 Conclusions

Gun movement in azimuth is highly sensitive to target velocity; elevation gun movement is relatively insensitive to target velocity.